I. C. 6915 November 1936

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
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SOME PROBLEMS OF RESPIRATORY PROTECTION IN THE PETROLEUM INDUSTRY, WITH SUGGESTIONS FOR THEIR SOLUTION

BY

G. M. KINTZ AND H. C. FOWLER

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SOME PROBLEMS OF RESPIRATORY PROTECTION IN THE PETROLEUM INDUSTRY, WITH SUGGESTIONS FOR THEIR SOLUTION[1]

By. G.M. Kintz[2] and H.C. Fowler[3]

Proper respiratory protection of workmen, regardless of the industry or the individual occupation, is fundamental for their health, safety, and efficiency. The problems involved in providing this protection have virtually the same elements, although it is unlikely that two jobs, even on the same type of work, will have exactly the same hazards. Satisfactory solution of problems created by atmospheric conditions that are unsafe or detrimental to the health and efficiency of workers can be reached only after careful analysis of individual circumstances. The specific impurity in the air to which each worker on each job is exposed must be determined, its dangers recognized, and effective protective measures taken - measures that not only protect but offer a minimum of inconvenience to the worker. Health and safety studies of respiratory hazards require a broad knowledge of the physiological effects produced by various dusts, mists, fumes, and gases and of the physical and chemical reactions that permit quantitative detection and elimination of these substances from the air breathed by workmen.

The literature pertaining to protection against toxic gases in the petroleum industry is extensive, but writings dealing with dusts and other extraneous air-borne material peculiar to that industry are relatively few. Accordingly, this paper deals mainly with hazards of the latter type and makes some suggestions as to protection against them. By drawing on the experience of other industries it is hoped that the information will help to promote greater health and safety among workmen and assist safety, personnel, and compensation departments in the petroleum industry to meet their individual problems, whether they pertain to burning lead, spraying paint, sand-blasting, cleaning and repairing tanks and stills, or other occupations in which men are exposed to respiratory hazards.

In preparing the following discussion of dust and related hazards in the petroleum industry, material has been drawn freely from and frequent reference is made to a series of publications prepared recently by the Health and Safety Branch of the United States Bureau of Mines, entitled "Review of Literature on Effects of Breathing Dusts, with Special Reference to Silicosis."[4]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6915."
Presented at the International Petroleum Exposition and Congress, Tulsa, Okla., May 21, 1936.

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Some idea of the importance of the problem of respiratory protection and the tremendous cost incident to this type of hazard may be gained from the following figures:

South Africa has paid over $65,000,000 in compensation for silicosis alone and has an additional outstanding liability of $34,000,000; in 1932 claims totaling $6,000,000 were allowed. In Wisconsin during 1932 approximately $207,000 was paid in compensation for occupational diseases, and from 1930 to 1932, inclusive, the indemnity cost of the State for occupational diseases increased over 80 percent, while accident compensation, in contrast, fell more than 30 percent[5]. The experience of other States in this regard could be cited, but in this discussion it will suffice to observe that lawsuits in the courts of the United States at present involve claims of more than $100,000,000 for silicosis, and Sappington[6] estimates that these claims increased nearly 200 percent over those in the previous year. Although some of these claims will not be allowed and other cases will be thrown out of court litigation is expensive, and judgments of the order of $14,000 and $21,000 are not uncommon. Hundreds of cases are being settled for smaller amounts.

An increasing interest in social security is evidenced by laws now being considered and passed in many States relating to hazards caused by occupational diseases and to compensation for people affected by those diseases. The interest of industries also is increasing in this vital problem, which is not new. However, because industry generally has not taken a greater interest in preventive measures in the past, much future trouble may be expected, and large sums of money probably will be paid as compensation.

An indication of the growing realization of the importance of proper atmospheric conditions is found in the annual expenditures now being made to air-condition office buildings, factories, and many working places by means of ventilating systems of proper design to keep the air free of hazardous substances[7] Although the scope of this paper is confined to discussions of individual protection against respiratory hazards, the importance of a positive system for properly ventilating buildings, specific work, or working places should not be overlooked.

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[4] Harrington, D., and Davenport, Sara J., Review of Literature on Effects of Breathing Dusts, with Special Reference to Silicosis. Part 1. Chapter 1. Definition and Classification of Dusts. Chapter 2. Sources of Exposure to Dusts. Chapter 3. Physiological Effects of Breathing Dusts: Information Circular 6835, Bureau of Mines, 1935 68 pp. Part II-A. Chapter 4. Prevention of Dust Diseases (Sections 1 and 2): Information Circular 6840, Bureau of Mines, 1935 117 pp. Part II-B. Chapter 4. Prevention of Dust Diseases (Sections 3 - 5): Information Circular 6848, Bureau of Mines, 1935 210 pp. Part III-A. Chapter 5. Economic and Legal Aspects of Dust Disease in Industry (Sections 1 and 2): Information Circular 6857, Bureau of Mines, 1935 266 pp.

[5] Griff, W.M., The Responsibility of the Health Department for Occupational Disease Control: Safety Engineering, vol. 68, September 1934, pp. 123-126.

[6] Sappington, C.O., Discussion of paper by Dick, P.G., Role of X-Ray in Industrial Hygiene: Ind. Med., vol. 4, 1935, p. 161.

Many people believe that silica dust is the only dust that affects the lungs adversely and that silicosis is a disease that has been recognized only in comparatively recent years. Neither idea is correct, nor is the use of respiratory protective equipment new. Hippocrates, born about 460 B. C., spoke of a metal digger as a man who breathed with difficulty and had other symptoms similar to those found in silicosis. Celsus, a Roman medical writer who lived in the first century, wrote: "By far the most terrible form of emaciation is that which the Greeks called phthisis. It spreads to the lungs. On top of this ulceration occurs and a slow fever, which at times disappears and at other times reappears." According to Harrington and Davenport[8], "Probably the oldest published datum regarding the harmfulness of exposure to dust is the statement in Pliny's Natural History that "Minium (red oxide of lead) refiners in the factory envelop their faces with loose bladders, which enable them to see without inhaling the fatal dust." This reference is of special historical interest, as it is probably the first mention of protective equipment against the hazards of dust. Pliny lived from 25 to 79 A.D.

From about 1551, when Amatus Lusitanus reported that "most workers occupied with the preparation of gypsum and lime died of lung phthisis," reports of the disease and various steps of protection against it have been more or less continuous. Phthisis now is considered generally as being synonymous with tuberculosis, and although many people use the word "silicosis" as a general term, actually the application is only to disease caused by silica dust. Pneumoconiosis (from the Greek _pneumon_, lung, and _konis_, dust) is the general term now being applied to all dust diseases of the lungs, whether caused by fibrous or nonfibrous substances, and it is likely that this word will be heard more and more. Other names given special dust diseases are silicatosis, anthracosis, siderosis, and asbestosis, which are causes, respectively, by the fine particles of various silicates, coals, iron or iron ores, and asbestos.

To facilitate the following discussion the subject has been divided into four subheadings:

1. What is a dangerous "atmosphere"?
2. Detectors for testing possible hazardous atmospheres.
3. Equipment for protection.
4. Use of equipment by workers.

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[7] According to Business Week, May 2, 1936, p. 19, $48,000,000 was spent for air conditioning in the United States in 1935.

[8] Work cited, Inf. Circ. 6835, p. 9.

WHAT IS A DANGEROUS ATMOSPHERE?

A safe atmosphere is more easily defined with accuracy than a dangerous one. A possible definition for a dangerous atmosphere is: An atmosphere is dangerous when it contains one or more foreign substances, such as gas, dust, mist, or fumes, in sufficient quantity to be harmful or explosive, or when it does not contain enough oxygen to allow working with maximum efficiency or to support life, or when the temperature and humidity are too high for human endurance.

Research has ascertained that under some circumstances certain gases (such as hydrogen sulphide, carbon monoxide, chlorine, and sulphur dioxide), certain fumes (such as mercury vapor, acid, and lead-burning fumes), and certain mists(such as paint, lacquer, and some insecticide sprays) are dangerous to health. Other examples could be named in each of the above catagories. Some authorities believe that breathing any kind of dust may lead to injury of the lungs if it is in sufficient concentration and breathed long enough, although to date this theory has not been accepted generally. Some persons claim (and there are cases that appear to bear out the theory) that the presence of an irritating gas or air of abnormal content will cause the dust to affect the respiratory organs more readily.

Dust need not be visible to be dangerous; in fact, virtually all dust experts believe that the most dangerous dust particles cannot be seen by the naked eye. They range in size from 0.5 micron to 2 microns or possibly up to 10 microns. (A micron is one-thousandth of a millimeter or approximately 1/25,000 inch.) Harrington and Davenport[9] state:

> The size of particles in prolonged suspension in the air is more likely to be under 5 microns than over; probably the most dangerous dust is that ranging from 2 microns to 0.5 micron or smaller because these impalpable particles readily remain in suspension in the air for long periods of time. The size of fume particles ranges from 1 to 0.2 micron in diameter. In other words, it is thought that the smaller the particles the greater the danger, although there may be a lower limiting size as well as a higher one; unless especially warned, employers and workmen are prone to regard impalpable nonvisible dust as altogether harmless. Dust particles under 5 microns in size readily pass through the mouth and nose, traverse the bronchial passages, and lodge in the alveolar tissue, from which remote parts of the lung structure they usually cannot be dislodged by hawking or coughing.

No one seems to be able to state with exactness the safe size and number of dust particles that may be in the air. An information circular in preparation by the Health and Safety Branch of the Bureau of Mines includes a statement that mountain air contains 2 large particles per cubic centimeter, while city air contains 15 to 100 such particles per cubic centimeter. The following regulation of the Industrial Commission of Wisconsin[10] is an example of the dust standards that are being set up for industry by some of the States:

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[9] Work cited, Inf. Circ. 6840, p. 86.

> The maximum silica-dust concentration considered permissible in the air breathed by a workman at any point in the normal breathing zone has not been definitely established. The commission, its advisory committee, employers, and scientists have agreed on a tentative figure of 15 million countable dust particles under 10 microns in longest dimension with free-silica content of 35 percent in a cubic foot of the air as determined by the United States Public Health Service technique. Variations in free-silica content will make proportional inverse changes in this standard. In the case of practically pure silica the permissible dust count would be 5,250,000 countable particles. By countable particles is meant those particles within the range of size from 2 to 10 microns in the longest dimension. Dust particles larger than 10 microns in the longest dimension do not ordinarily reach parts of the body where they can produce injury.

From the foregoing discussion it can be seen that despite the extended study given to the hazard of dust definite and exact information is meager. Harm to the respiratory system caused by dust, like that caused by gases, mists, and fumes, depends upon the concentration and the length of exposure; but unlike these substances, the size of the dust particles enters into the hazard. Because of the very nature of this problem, which pertains to certain causes and their effects upon the human body under various and varying circumstances, and because the required technique of dealing with the subject cannot be reduced to the exactness of a mathematical equation, safety engineers and all others concerned with dust hazards will do well to "play safe" by protecting, insofar as feasible, against any atmosphere that is not normal.

Some of the more common occupations in the petroleum industries where respiratory protection may be needed are cleaning tanks, gaging, sand-blasting, handling coke, cleaning coke out of stills, cleaning brick, handling dusty materials (such as fullers earth, cement, lime, gypsum, clays, and dry caustics), certain welding operations, burning lead, burning off paint, paint-spray work, brush painting in close quarters, and the many operations in which workmen are exposed to dust and hydrogen sulphide gas.

About 10 years ago hydrogen sulphide poisoning was considered an outstanding hazard of the petroleum industry. Field and plant workmen knew little or nothing about the toxic effects of hydrogen sulphide, and even safety engineers were at a loss regarding the application of sure and practical methods of protection. That condition has been changed radically, and through persistent education the industry in general knows about hydrogen sulphide gas, workmen respect its toxic qualities, and most companies are fairly well equipped to combat this hazard.

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[10] See Harrington, D., and Davenport, Sara J., Work cited: Inf. Circ. 6840, pp. 88 and 89.

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DETECTORS FOR TESTING POSSIBLE HAZARDOUS ATMOSPHERES

The development and commercial manufacture of efficient and accurate detectors for testing the percentages of poisonous, irritating, and inflammable gases and vapors that may be present in the atmosphere have been great boons to those engaged in health and safety work. Only within recent years has this condition been brought about, and the petroleum industry has made wide use of many of these devices as they have become available in helping solve its problems of protecting the lives and health of its employees. Many safety engineers require one or more of them as an essential part of their safety equipment and are thoroughly familiar with their construction and operation. Nevertheless, a brief resumé of the operating principles of several detectors is given, with full recognition of the fact that the best way to obtain definite knowledge about them and to gain proficiency in their operation is to inspect them and use them under test conditions.

Detectors for Inflammable Gas

Detectors for inflammable gas that are in most common use are known as the J. W., M.S.A., and U.C.C. The several detectors differ in construction but operate on essentially the same principle, namely, that when an electrically heated filament is introduced into an atmosphere containing inflammable gas, the electrical resistance of the filament will vary in direct proportion to the amount of inflammable gas present. The variation of the resistance is recorded on a meter graduated in percentage of gas or percentage of explosibility. The instruments are reasonably accurate for percentages from zero to the explosive limits.

The Burrell detector for inflammable gas has not been used as generally as those that have been mentioned. The operation of this detector is based on the principle that the products of combustion of most inflammable gases have less volume at the same temperature and pressure than the gas that is burned. The decrease in volume is in direct proportion to the amount of gas burned.

A number of continuous inflammable gas detectors are on the market, but they are not intended to be used as portable instruments and are not described in this paper.

Detectors for Toxic Gases

Carbon-Monoxide detectors

Hoolamite detector. - When carbon monoxide (CO) is passed through ground pumice saturated with iodine pentoxide in the presence of fuming sulphuric acid, free iodine is liberated, which stains the pumice a greenish color. By comparing the shade of green obtained by a measured volume of air with a color scale, the amount of carbon monoxide can be determined. The range of this instrument is 0.05 to 1 percent. Its accuracy depends somewhat on the ability of the individual to estimate the true shades. This device is used extensively by the Bureau of Mines, manufactured-gas companies, and others desiring to ascertain the presence of carbon monoxide.

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Pyrotannic acid detector. - This device is compact but requires a little technique in its operation and is used primarily for detecting the presence of carbon monoxide in the blood. It is very accurate and will detect from zero to 0.2 percent of the gas in the air. It operates on the principle that the affinity of carbon monoxide for the hemoglobin of the blood is about 300 times that of oxygen. To test the atmosphere for carbon monoxide a small bottle is filled with the air to be examined, and 0.1 cm^3 of blood, which is diluted to 2 cm^3 with distilled water, is placed in the bottle. After about 15 minutes of agitation this blood solution is treated with a compound of pyrotannic-pyrogallic acid and the resulting color compared with a standard color scale.

Continuous carbon monoxide detectors. - These detectors are made in stationary and portable models. All models require a supply of electric current. (Dry-cell or storage batteries may be used.) The operation of these machines is based on the fact that when carbon monoxide passes through a compound known by the trade name of "Hopcalite" it is converted to carbon dioxide and thus generates heat. The amount of heat generated is in direct proportion to the amount of carbon monoxide present. By means of thermocouples the amount of heat is recorded on a dial marked in percentage of carbon monoxide present. These instruments are accurate, the portable type having a dial graduated to 0.01 percent.

Carbon monoxide-detector ampoule. - This device consists essentially of a solution of palladium chloride in acetone-water, which is sealed in a small glass vial surrounded by absorbent cotton. When the vial is crushed the solution saturates the cotton. The ampoule is then hung in the atmosphere to be tested for approximately 10 minutes. If carbon monoxide is present the solution on the cotton will become gray to grayish, depending on the concentration.

Hydrogen Sulphide Detectors

Although hydrogen sulphide (H_2S) has a definite odor (the so-called "rotten-egg" smell) in minute quantity, the odor cannot be depended upon to give warning; generally speaking, as long as the hydrogen sulphide can be smelled the person exposed to the gas is safe.

M.S.A. hydrogen sulphide detector. - Chemists of the Bureau of Mines recently have perfected a portable means of detecting hydrogen sulphide. The detector depends upon the use of silver cyanide on activated alumina. When a measured volume of the air containing hydrogen sulphide is forced through a tube containing this material it turns black, and the length of the discoloration in the tube is a measure of the percentage of the gas present.

Lead acetate paper. - This method has been used to detect hydrogen sulphide, but it is not positive and its accuracy is limited. The method consists of saturating a piece of absorbent paper with lead acetate and placing the paper in the atmosphere to be tested. Discoloration indicates that hydrogen sulphide is present.

Detector for Atmosphere Deficient in Oxygen

Flame Safety Lamp

Lack of oxygen in the air can cause death as readily as most toxic gases. The quickest (though not always the safest) way to tell whether an atmosphere is deficient in oxygen is to see if a flame will burn in it; it is not advisable to use an open flame for this purpose because of the possible presence of explosive gas. At present the flame safety lamp is the best portable device for determining whether enough oxygen is present to support life. However, this lamp is not a foolproof device, and a number of explosions with heavy loss of life have resulted from its misuse; in fact, some large petroleum organizations now prohibit the use of the flame safety lamp. Only a properly assembled flame safety lamp should be used and then only by a person who has been trained in its use and fully understands its hazards, construction, and proper assembly.

Instruments for Counting and Recording Amount of Dust in Air

A number of different devices are on the market and in use for determining the size and amount of dust particles in the air. To operate these instruments requires practice and skill. In general, a sample of the dust particles in the atmosphere is collected by some suction method, taken to the laboratory or similar place, and counted by means of a microscope or by weighing. Some of the instruments used are the impinger, electrical precipitator, paper thimble, Owens jet dust counter, and konimeter. Recently other instruments have appeared on the market, such as the continuous dust recorder invented by Professor Drinker and the Ficklen-Ott dust camera.

Human beings cannot depend upon their sense of smell or sight to tell whether or not an atmosphere is dangerous. Animals usually have a far superior sense of smell and sight than is possessed by human beings but even they cannot always indicate whether poisonous gases, dust, fumes, or mist are present in the surrounding atmosphere. Either chemical analysis or the proper detector should be used to indicate the presence of gas. Dependence upon smell, sight, taste, or any other human sense in an effort to determine the presence of a poisonous or otherwise harmful gas, mist, fume, or dust is a dangerous practice.

EQUIPMENT FOR PROTECTION

Selection of the proper individual equipment to condition the air breathed by men working on a job with a potential respiratory hazard is very important. Before a selection is made most of the following question must be answered:

1. Is there enough oxygen to support life?
2. What toxic of asphyxiating gases are present and what are their concentrations and characteristics?
3. What dusts, mists, fumes, or combinations of these are present and in what concentration?
4. How long will the period of exposure be?

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5. What is the temperature and humidity of the atmosphere where men will be working?

6. Under what conditions will men be working? That is, will they be in cramped quarters and is the opening small through which they must enter or leave?

7. Will a continuous current of air be ventilating the enclosures?

8. Will work be routine or emergency?

9. Will work cover a large or small area?

10. How much of the head and body should be protected? That is, will it be sufficient to cover just the nose and mouth or should the eyes or even the entire head be protected?

11. What is the physical condition of the worker and what are his facial characteristics?

The answers to these questions will largely indicate the proper type of protective equipment to be selected. The selection will be limited further when the following advantages and disadvantages of the more common types are considered.

Canister-Type Gas Mask

This protective equipment consists of a full or half facepiece, or a mouthpiece and nose clip, which is attached by means of a flexible rubber tube to a canister hung in front of or on the back of the wearer.

Advantages. - The mask is light in weight, occupies little space, is easy to transport, and filters out most dusts and mists if the gases or mists are present in limited percentages or quantities.

Disadvantages. - The mask cannot be worn with safety in an atmosphere deficient in oxygen or in an atmosphere containing more than 2 percent, by volume, of any toxic gas except ammonia, when it will give protection to 3 percent. The facepiece must fit tightly to the face; any leaks indicate that the mask is ineffective and may cause death to the wearer. The mask can be worn only in that class of gas for which the canister is designed - the type N (all-service) canister protects against limited percentages of all gases. In a warm and humid atmosphere or during hard work the face perspires, the resistance of the canister increases rapidly, and the mask becomes uncomfortable to wear; sometimes, too, the rubber may irritate the skin. The mask can be worn in safety only for the length of time indicated on the canister. A man may enter a dangerous atmosphere without one or more other persons being present, a practice that, even with any type of respiratory-protective equipment, exposes the wearer to the hazard of losing his life. Some prominent petroleum organizations prohibit the use of canister gas masks and stimulate that emergency respiratory protection must be obtained by using a suitable fresh air-hose mask.

Dust Respirators

Dust respirators generally consist of half facepieces to which are attached an exhaust valve and a filtering medium that removes the dust from the inhaled air; some are equipped with a filter medium that removes paint mists and some fumes.

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Advantages. - They are light in weight and inexpensive; those approved by the United States Bureau of Mines are effective.

Disadvantages. - They cannot be worn in an atmosphere that contains toxic gases or fumes or that is deficient in oxygen. Filter pads must be changed at certain intervals, depending on the concentration of dust or mists. The facepiece must fit tightly to the face and has the same disadvantage as the canister-type mask in warm, humid atmospheres. Some types restrict the field of vision.

Self-Contained Oxygen Breathing Apparatus

This apparatus consists chiefly of a mouthpiece fastened by a flexible hose and various reducing valves to a tank of oxygen under high pressure; it is a rather complicated machine and weighs 12 to 21 pounds for the half-hour type and about 40 pounds for the 2-hour type.

Advantages. - The machine can be worn in any atmosphere that will not irritate or poison the skin, when properly assembled and equipped with the proper rubber parts in good condition.

Disadvantages. - It is bulky, heavy, and rather expensive to purchase and maintain; the wearer must have special training in its use before he can wear it with safety. (This apparatus is not in general use in the petroleum industry.)

Hose Masks and Air-Line Respirators

Hose Masks and Respirators with Positive Air Supply

These masks have essentially the same type of facepiece as described for the canister mask, but instead of being fastened to a canister it is connected to a supply of fresh, pure air. The supply may be furnished by a blower, hand or electrically operated, or by an air compressor, the intake of which should be in pure air.

Advantages. - The mask is light in weight and costs little to maintain. The air is supplied under positive pressure; therefore, as long as the pure-air supply is maintained there is little danger that the worker will inhale foul air through a leak around the facepiece. The inflowing air reduces excessive perspiration and tends to cool the face. When a hand-operated blower is used a second person is always present. (With the approved mask, provided the facepiece is tight, the wearer can inhale enough air through the hose to escape if the blower should stop.) Permissible hose masks can be worn in any atmosphere that will not poison or irritate the skin, but the directions on the approval plate should be followed explicitly.

Disadvantages. - The mask and blower cost more than a canister mask. The area of travel is limited to the length of the hose, and movements are handicapped to some extent by the hose. Manifestly, the air for the hose and the mask should be fresh and pure, but unfortunately this is not always so.

Hose Mask Without Positive Air Supply

This mask is essentially the same as the hose mask just described, except that it is not connected to a blower. The intake of the hose is placed in fresh air, and the wearer pulls or sucks the air through the hose.

Advantages. - The mask can be worn in any atmosphere that will not poison or irritate the skin, although it is not recommended for use in highly toxic gases.

Disadvantages. - It must fit tightly to the face. The distance the wearer may travel is very limited. It may be uncomfortable to wear the facepiece in hot, humid atmospheres, and the air manifestly should be pure at its source.

Helmet-Type Respirators

This protective equipment consists of a hood with windows that fits loosely over the head and shoulders; a supply of fresh air, at least 6 cubic feet per minute, is blown into the hood.

Advantages. - The head and shoulders are covered, protecting the skin against abrasives. The incoming air cools the head. It is relatively safe to wear in dusty atmospheres but is not approved for use in poisonous gases or fumes, in which its safe use is doubtful.

Disadvantages. - The mask should be worn only in places from which the wearer can escape without danger if the air supply should fail, as it gives absolutely no protection in case of such failure.

The Bureau of Mines will approve equipment of any of the above types if such equipment meets the Bureau's test requirements, and many types are now on the market. As suggested, with reference to detectors for testing possible hazardous atmospheres, definite knowledge of the construction and operation of protective equipment should be gained by inspection.

USE OF EQUIPMENT BY WORKERS

Selecting the equipment is simple compared with getting men to wear it after it is supplied. Generally workmen will wear masks readily in places where they have seen others asphyxiated, or in some similar trouble, but they are likely to resist wearing protective equipment where the dust cannot be seen or where the fumes and mist have no objectionable odor. There are three main reasons for such resistance: First, inbred objection to any new idea; second, the feeling that the individual is a superman and can "take it" without protection; and, third, the inconvenience of wearing the equipment.

Many plans that look workable on paper could be suggested for establishing respiratory protection, but in practical operation difficulties usually are experienced. Probably the simplest plan is first to "sell" the supervising official, which should not be difficult if he is safety-minded; otherwise, strict orders from higher officials may be necessary. Then the worker must be "sold" by education, possibly accompanied by strict and fair supervision and discipline.

When the hydrogen sulphide problem first presented itself in oil fields of the southwestern United States and at refineries processing high-sulphur crude oils, the statement was often made that the men could not or would not work with respiratory protective equipment. Usually it was found that these statements were based upon prejudice or lack of knowledge rather than fact. Systematic educational work has overcome this prejudice largely and has proved to the workmen and the industry that suitable protection is needed and can be worn in dangerous concentrations of gas.

CONCLUSION

There is still a tremendous amount to be learned about industrial diseases. One thing, however, is certain - there is a very definite tendency to require compensation for them. If companies and safety engineers wish to keep compensation costs at the minimum and to promote the health and safety of the workmen, they will lose no time in taking adequate precautionary measures. Every forward-looking employer will take steps to become fully informed on the subject of occupational hazards and on methods and equipment likely to aid in combatting them in order that he may put his house in order. He will make every possible effort to have each working place ventilated as thoroughly as practicable. Moreover, he will see that every workman or any other person wears proper protective equipment when exposed for a prolonged period to an atmosphere that contains gas, dust, mists, or fumes in sufficient concentrations to be dangerous, or when exposed for short periods to atmospheres that contain considerable quantities of harmful gases or dusts.

Financial expenditures probably will have to be made to avoid hazardous atmospheres and to provide protective equipment, and time and thought will be required to perform this work and to educate workmen in the necessity of wearing the proper protective equipment.

The authors are indebted to D. Harrington, chief engineer, and Sara J. Davenport, principal translator, Health and Safety Branch, United States Bureau of Mines, for their assistance in preparing this paper.